LEVEL (12) ARO 14932.8-E

AD A109151

THE VALUE OF DYNAMIC FRACTURE TOUGHNESS
AND ITS DEPENDENCE ON MATERIAL PROPERTIES
AND LOADING CONDITIONS

by
GEORGE HERRMANN

DECEMBER 1981

FINAL REPORT

U. S. ARMY RESEARCH OFFICE

DAAG29-78-G-0086

STANFORD UNIVERSITY

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A109	3. RECIPIENT'S CATALOG NUMBER 157
4. TITLE (and Subtitle) The Value of Dynamic Fracture Toughness and its Dependence on Material Properties and Loading Conditions		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) George Herrmann		8. CONTRACT OR GRANT NUMBER(s) DAAG29-78-G-0086
9. PERFORMING ORGANIZATION NAME AND ADDRESS Division of Applied Mechanics Stanford University Stanford, CA 94305 420389		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS P-14932-E
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Research Office Post Office Box 12211 Research Triangle Park, NC 27709		12. REPORT DATE December 1981
		13. NUMBER OF PAGES 4
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

NA

18. SUPPLEMENTARY NOTES

The view, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

fracture toughness
dynamic fracture
fracture of beams
tensile fracture

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Investigation of dynamic fracture of long brittle beams under different loading conditions was effected under ARO Grant DAAG29-78-G-0086. The work has proceeded in two distinct areas - the numerical solution of crack propagation problems using a finite difference code and the analytical solution of some beam fracture problems using several one-dimensional theory formulations.

DD FORM 1473 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Investigation of dynamic fracture of long brittle beams under different loading conditions was effected under ARO Grant DAAG29-78-G-0086. The principal investigator was Professor G. Herrmann of Stanford University. Other scientific personnel involved in the research were Professor M. Shmuely, visiting professor from the Israel Institute of Technology (Technion) and Mr. C. Levy, graduate student at Stanford.

The work has proceeded in two distinct areas - the numerical solution of crack propagation problems using a finite difference code and the analytical solution of some beam fracture problems using several one-dimensional theory formulations.

The motion of the crack tip for the double cantilever beam (DCB) specimen and for the single edge-notch specimen (SEN) was obtained for several loading conditions by means of the SMF2D Code proposed by Shmuely and Perl in a recent paper. The numerical results for the DCB model were compared with the experimental results of Kalthoff et al. and found to be within good agreement numerically as well as qualitatively. Because no experimental results existed for the acceleration stage of the propagating crack, several test functions for the acceleration stage were formulated. These functions showed no appreciable effect on the acceleration of the crack, but did show definite effects on the deceleration stage of the propagating crack.

The code was also applied to the SEN model for which experimental results do not exist. It was found that in all cases the dynamic stress intensity factor characteristics depended strongly on initial crack length and final crack velocity. All cases showed the characteristic decrease in dynamic stress intensity factor as the crack started to propagate, thereby confirming the results of Freund for a half-plane crack propagating in an unbounded medium (where reflection of stress waves from the boundary to the crack tip do not play an important role).

Based on the results obtained, the SMF2D Code was found to be a very good numerical tool for predicting crack behavior within the limitations of the code. As a result of this, a paper was submitted for publication and the work on the numerical solution of crack propagation problems (M. Shmuely and C. Levy, "The Dependence of the Dynamic Material Toughness on the Velocity and on some Loading Parameters") is now in print in the International Journal of Fracture.

The second area of endeavor is an attempt to use a modified quasi-static approach to the fracture of infinitely long beams under the assumption that e crack propagation velocity is much smaller than any of the characteristic e speeds of the beam. The problems that have been solved analytically have been motivated by earlier work.

The analytical investigation of dynamic fracture of long brittle beams under two different loading systems was undertaken assuming that the crack propagation velocity was smaller than any of the characteristic wave speeds of the beam. This assumption allowed us to formulate the problems via a modified quasistatic approach. To make the problems more tractable, the one-dimensional beam models of Euler-Bernoulli, Rayleigh and Timoshenko (without rotary inertia) were incorporated in the problem formulation. The loading (statically applied) was either remote axial tension or remote pure bending and the results obtained were the crack tip velocity-time history; the crack tip displacement-time history; the bending moment and the extensional load on the fracturing cross-section. To preclude reflection effects, the beam was considered to be infinite in length. The results obtained showed that fracture is not complete for either applied loading, but requires the accounting of the reflection process for fracture to be total. The following results do not account for the reflection process, but this feature is now under investigation.

The simplest beam model studied was that of Euler-Bernoulli. The analytical formulation for the beam under remote applied bending moments may be found in the literature. However, an error exists in the formulation of the problem and when corrected, brings the results closer to earlier experimental observation. To investigate the rotary inertia effects on the bending moment and extensional loading at the fracturing cross-section, the Rayleigh beam model was employed. With respect to the results of the Euler-Bernoulli model, for a given initial crack length, the rotary inertia tended to retard crack growth, to decrease the bending moment and to increase the extensional load on the fracturing cross-section; and to reduce the crack tip velocity over the majority of the beam height.

The final model investigated was the Timoshenko beam model. The Timoshenko model was employed in order to show the shear effects on the data to be obtained. With respect to the results of the Euler-Bernoulli model for a given initial crack length, the shear tended to enhance crack growth; to increase the bending moment and to decrease the extensional load on the fracturing cross-section; and to increase the crack tip velocity over most of the beam height. Thus by "averaging" the data of these last two models we found that the overall results were either close to the Euler-Bernoulli model or favored very slightly, the Rayleigh beam model data. This "averaging" could be considered a first order approximation to the Timoshenko beam model and the results tended to show that the Euler-Bernoulli theory provided us with an adequate model for the dynamic fracture of infinitely long notched brittle beams under varied loading conditions. In all it is found that all the models adequately describe the fracture process until wave reflection effect came into play. This second area has resulted in six manuscripts that have been submitted for publication:

1. On the Effect of Axial Force on Dynamic Fracture of a Beam or Plate in Pure Bending
2. Dynamic Fracture of a Beam or Plate under Tensile Loading.
3. Symmetric Dynamic Fracture of a Beam or Plate under Tensile Loading
4. Effect of Bending Moment on the Dynamic Fracture of a Beam or Plate under Tensile Loading
5. Effect of Shear and Rotary Inertia on Dynamic Fracture of a Beam or Plate under Tensile Loading
6. Effect of Shear and Rotary Inertia on Dynamic Fracture of a Beam or Plate in Pure Bending